

Electricity and Magnetism, India, NPLI (National Physical Laboratory of India)

Calibration or Measurement Service			Measurand Level or Range			Measurement Conditions/ Independent Variable		Expanded Uncertainty							
Quantity	Instrument or Artifact	Instrument Type or Method	Minimum Value	Maximum Value	Units	Parameter	Specifications	Value	Units	Coverage Factor	Level of Confidence	Is the expanded uncertainty a relative one?	Matrix uncertainty	Comments	NMI Service Identifier
DC voltage sources: single value	Solid state voltage standard	Comparison	1	1	V			80	nV	2	95%	No			1
DC voltage sources: single value	Solid state voltage standard	Comparison	1.018	1.018	V			80	nV	2	95%	No			1-1
DC voltage sources: single value	Standard cell	Comparison	1.018	12	V			1	$\mu\text{V/V}$	2	95%	Yes			2
DC voltage sources: low values ($\leq 10\text{ V}$)	DC voltage source, multifunction calibrator	Resistive divider	1E-05	10	V			1.5 to 15	μV	2	95%	No			3
DC voltage sources: intermediate values ($> 10\text{ V}$ to 1100 V)	DC voltage source, multifunction calibrator	Resistive divider	10	1000	V			1.5 to 4.5	$\mu\text{V/V}$	2	95%	Yes			4
DC voltage meters: very low values ($\leq 1\text{ mV}$)	DC voltmeter, multimeter	Resistive divider	1E-05	1E-03	V			1.5	μV	2	95%	No			5
DC voltage meters: intermediate values ($> 1\text{ mV}$ to 1100 V)	DC voltmeter, multimeter	Resistive divider	1E-03	10	V			1.5 to 15	μV	2	95%	No			6
DC voltage meters: intermediate values ($> 1\text{ mV}$ to 1100 V)	Multifunction transfer standard, DC voltmeter	Resistive divider	10	1000	V			1.5 to 4.5	$\mu\text{V/V}$	2	95%	Yes			7

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DC voltage ratios (for input voltages up to 1100 V)	Resistive divider	Comparison with reference divider	100:10	1000:10		Input voltage	1 V to 1000 V	2	$\mu\text{V}/\text{V}$	2	95%	Yes			8
DC resistance standards and sources: low values ($\leq 1 \Omega$)	Fixed resistor, resistance box	Direct current comparator bridge	0.1	1	Ω			1.5 to 5	$\mu\Omega/\Omega$	2	95%	Yes			9
DC resistance standards and sources: intermediate values ($> 1 \Omega$ to 1 M Ω)	Fixed resistor, resistance box	Direct current comparator bridge	1	1E+06	Ω			1.5 to 5	$\mu\Omega/\Omega$	2	95%	Yes			10
DC resistance standards and sources: high values ($> 1 \text{ M}\Omega$)	Fixed resistor	Comparison	1E+07	1E+14	Ω			0.2 to 80	$\text{m}\Omega/\Omega$	2	95%	Yes			11
DC resistance standards and sources: multiple ranges	Multifunction calibrator	Comparison	10	1E+06	Ω			0.1 to 1	$\text{m}\Omega/\Omega$	2	95%	Yes			12
DC resistance meters: low values ($\leq 1 \Omega$)	Ohmmeter, multimeter, resistance bridge	Comparison	0.1	1	Ω			1.5	$\mu\Omega/\Omega$	2	95%	Yes			13

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DC resistance meters: intermediate values ($> 1 \Omega$ to $1 \text{ G}\Omega$)	Ohmmeter, multimeter, resistance bridge	Comparison	1	$1\text{E}+06$	Ω			1.5 to 5	$\mu\Omega/\Omega$	2	95%	Yes			14
DC resistance meters: intermediate values ($> 1 \Omega$ to $1 \text{ G}\Omega$)	Resistance bridge	Comparison	1	10	$\text{M}\Omega$			5	$\mu\Omega/\Omega$	2	95%	Yes			14-1
DC resistance meters: intermediate values ($> 1 \Omega$ to $1 \text{ G}\Omega$)	Resistance bridge, teraohmmeter	Comparison	$1\text{E}+07$	$1\text{E}+09$	Ω			0.2 to 1.0	$\text{m}\Omega/\Omega$	2	95%	Yes			14-2
DC resistance meters: high values ($> 1 \text{ G}\Omega$)	Resistance bridge, teraohmmeter	Comparison	$1\text{E}+09$	$1\text{E}+14$	Ω			1 to 80	$\text{m}\Omega/\Omega$	2	95%	Yes			15
DC current sources: low values (≤ 0.1 mA)	Current generator, calibrator	Voltage drop across reference resistor	1	100	μA			5.5	$\mu\text{A}/\text{A}$	2	95%	Yes			16
DC current sources: intermediate values (> 0.1 mA to 20 A)	Current generator, calibrator	Voltage drop across reference resistor	$1\text{E}-04$	2	A			5.5 to 7	$\mu\text{A}/\text{A}$	2	95%	Yes			17

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DC current sources: intermediate values (> 0.1 mA to 20 A)	Current generator, calibrator	Voltage drop across reference resistor	2	20	A			7 to 10	μA/A	2	95%	Yes			17-1
DC current meters: low values (<= 0.1 mA)	Multifunction transfer standard, multimeter	Voltage drop across reference resistor	1	100	μA			5.5	μA/A	2	95%	Yes			18
DC current meters: intermediate values (> 0.1 mA to 20 A)	Multifunction transfer standard, multimeter	Voltage drop across reference resistor	1E-04	2	A			5.5 to 7	μA/A	2	95%	Yes			19
DC current meters: intermediate values (> 0.1 mA to 20 A)	Multifunction transfer standard	Voltage drop across reference resistor	2	20	A			7 to 10	μA/A	2	95%	Yes			20
DC current meters: high values (> 20 A to 100 A)	Multifunction transfer standard	Voltage drop across reference resistor	20	100	A			10	μA/A	2	95%	Yes			21
AC resistance: real component	Resistor	Quadrature bridge	1	1	kΩ	Frequency	1592 Hz	1	mΩ	2	95%	No			22
AC resistance: real component	Resistor	Transform r ratio bridge	1	1E+06	Ω	Frequency	1 kHz	5 to 300	μΩ/Ω	2	95%	Yes			23

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AC resistance: meters	LCR meter	Direct measureme nt or comparison	1	1E+07	Ω	Maximum frequency	10 MHz	1 to 30	m Ω / Ω	2	95%	Yes			24
Capacitance: capacitance and dissipation factor for low loss capacitors	Silica capacitor	Transforme r ratio bridge	10	10	pF	Frequency	1592 Hz	6E-06	pF	2	95%	No			25
Capacitance: capacitance and dissipation factor for low loss capacitors	Air capacitor	Transforme r ratio bridge	10	1000	pF	Frequency	1 kHz	10	μ F/F	2	95%	Yes			26
Capacitance: capacitance and dissipation factor for dielectric capacitors	Mica capacitor	Transforme r ratio bridge	1E-03	1	μ F	Frequency	1 kHz	100	μ F/F	2	95%	Yes			27
Capacitance: dissipation factor	Fixed capacitor	Transforme r ratio bridge	5E-05	1E-03		Frequency	1 kHz	3E-05		2	95%	No			28
Capacitance: dissipation factor	Capacitance bridge	Direct measureme nt or comparison	1E-04	1E-03		Frequency	1 kHz	0.1	%	2	95%	Yes			29
Capacitance: meters	Capacitance bridge	Direct measureme nt or comparison	1E-03	1E+06	pF	Frequency	1 kHz	10 to 100	μ F/F	2	95%	Yes	LF Capacitance Bridge		30

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Capacitance: meters	LCR meter	Direct measureme nt or comparison	1	1000	pF	Maximum frequency	10 MHz	0.5 to 30	mF/F	2	95%	Yes			31
Inductance: self inductance and equivalent series resistance, low values (< 1 mH)	Inductor	AC bridges	1	100	μH	Frequency	1 kHz	10 to 0.5	mH/H	2	95%	Yes			32
Inductance: self inductance and equivalent series resistance, intermediate values (>= 1 mH to 1 H)	Inductor, Temperature controlled inductor	AC bridges	1	100	mH	Frequency	1 kHz	30 to 100	μH/H	2	95%	Yes	LF Inductance		33
Inductance: self inductance and equivalent series resistance, high values (> 1 H)	Inductor	AC bridges	1	10	H	Frequency	1 kHz	1 to 10	mH/H	2	95%	Yes			34
Inductance: meters	LCR meters	Direct measureme nt or comparison	10	1000	μH	Maximum frequency	10 MHz	1 to 30	mH/H	2	95%	Yes			35
AC/DC voltage transfer: AC/DC transfer difference at low voltages (typically <= 0.5 V)	Micropotentio meters	Comparison	1	500	mV	Frequency	10 Hz to 1 MHz	10 to 1000	μV/V	2	95%	Yes	AC-DC voltage difference		36

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AC/DC voltage transfer: AC/DC transfer difference at medium voltages (typically 0.5 V to 5 V)	Thermal voltage converter	Comparison	0.5	5	V	Frequency	10 Hz to 1 MHz	10 to 35	μV/V	2	95%	Yes	AC-DC voltage difference		37
AC/DC voltage transfer: AC/DC transfer difference at higher voltages (typically > 5 V)	Thermal voltage converter	Comparison	> 5	1000	V	Frequency	10 Hz to 1 MHz	10 to 100	μV/V	2	95%	Yes	AC-DC voltage difference		38
AC voltage up to 1000 V: sources	Multifunction calibrator	AC/DC transfer	0.003	1000	V	Frequency	10 Hz to 1 MHz	20 to 1000	μV/V	2	95%	Yes	AC voltage (source)		39
AC voltage up to 1000 V: meters	Transfer standard and digital multimeter	AC/DC transfer	0.003	1000	V	Frequency	10 Hz to 1 MHz	10 to 1000	μV/V	2	95%	Yes	AC voltage (measurement)		40
AC voltage ratio, attenuation and gain: real component	Inductive voltage dividers	Comparison	0	1		Frequency	55 Hz to 10 kHz	5E-08 to 1E-06		2	95%	Yes	LF IVD		41
						Maximum voltage	10 V to 100 V								
AC/DC current transfer: AC/DC transfer difference	Thermal converter and shunt	AC/DC transfer	0.005	20	A	Frequency	40 Hz to 10 kHz	20 to 100	μA/A	2	95%	Yes	AC-DC current difference		42

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AC current up to 100 A: sources	Transconductance amplifier	AC/DC transfer	1	20	A	Frequency	40 Hz to 10 kHz	100 to 200	µA/A	2	95%	Yes	AC current (source)		43
AC current up to 100 A: meters	Digital multimeter	AC/DC transfer	0.001	1	A	Frequency	40 Hz to 10 kHz	100	µA/A	2	95%	Yes	AC current (measurement)		44
AC power and energy: single phase power at frequency <= 400 Hz, active power	Power meters	Comparison	0.1	69120	W	Frequency	40 Hz to 400 Hz	(100 to 300)/cosϕ	µW/W	2	95%	Yes	Single Phase Active Power		45
						Voltage	10 V to 576 V								
						Current	0.01 A to 120 A								
						Power factor	0.01 I/C to 1 I/C								
AC power and energy: single phase power at frequency <= 400 Hz, reactive power	Power meters	Comparison	0.1	69120	var	Frequency	40 Hz to 70 Hz	(100 to 200)/sinϕ	µvar/var	2	95%	Yes	Single Phase Reactive Power		46
						Voltage	10 V to 576 V								
						Current	0.01 A to 120 A								
						Power factor	0.01 I/C to 1 I/C								

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AC power and energy: single phase power at frequency ≤ 400 Hz, apparent power	Power meters	Comparison	0.1	69120	VA	Frequency	40 Hz to 70 Hz	100 to 200	$\mu\text{VA}/\text{VA}$	2	95%	Yes	Single Phase Apparent Power		47
						Voltage	10 V to 576 V								
						Current	0.01 A to 120 A								
AC power and energy: single phase energy at frequency ≤ 400 Hz, active energy	Energy meters	Comparison	10	3600000	Ws	Frequency	40 Hz to 400 Hz	(100 to 300)/ $\cos\phi$	$\mu\text{Wh}/\text{Wh}$	2	95%	Yes	Single Phase Active Energy	Time at maximum range: 100 s and at minimum range: 1800 s	48
						Voltage	30 V to 300 V								
						Current	0.01 A to 120 A								
AC power and energy: single phase energy at frequency ≤ 400 Hz, reactive energy	Energy meters	Comparison	10	3600000	vars	Power factor	0.25 I/C to 1 I/C								
						Frequency	40 Hz to 70 Hz	(100 to 200)/ $\sin\phi$	$\mu\text{varh}/\text{varh}$	2	95%	Yes	Single Phase Reactive Energy	Time at maximum range: 100 s and at minimum range: 1800 s	49
						Voltage	30 V to 300 V								
						Current	0.01 A to 120 A								
						Power factor	0.25 I/C to 1 I/C								

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AC power and energy: single phase energy at frequency <= 400 Hz, apparent energy	Energy meters	Comparison	10	3600000	VAs	Frequency	40 Hz to 70 Hz	100 to 200	μVAh/V Ah	2	95%	Yes	Single Phase Apparent Energy	Time at maximum range: 100 s and at minimum range: 1800 s	50		
						Voltage	30 V to 300 V										
						Current	0.01 A to 120 A										
AC power and energy: three phase, active power	Power meters	Comparison	0.3	207360	W	Frequency	40 Hz to 400 Hz	(100 to 300)/cosϕ	μW/W	2	95%	Yes	Three Phase Active Power		51		
						Voltage	10 V to 576 V										
						Current	0.01 A to 120 A										
						Power factor	0.01 I/C to 1 I/C										
AC power and energy: three phase, reactive power	Power meters	Comparison	0.3	207360	var	Frequency	40 Hz to 70 Hz	(100 to 200)/sinϕ	μvar/var	2	95%	Yes	Three Phase Reactive Power		52		
						Voltage	10 V to 576 V										
						Current	0.01 A to 120 A										
						Power factor	0.1 I/C to 1 I/C										
AC power and energy: three phase, apparent power	Power meters	Comparison	0.3	207360	VA	Frequency	40 Hz to 70 Hz	100 to 200	μVA/VA	2	95%	Yes	Three Phase Apparent Power		53		

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						Voltage	10 V to 576 V								
						Current	0.01 A to 120 A								
AC power and energy: three phase, active energy	Energy meters	Comparison	30	10800000	Ws	Frequency	40 Hz to 400 Hz	(100 to 300)/cos ϕ	$\mu\text{Wh}/\text{Wh}$	2	95%	Yes	Three Phase Active Energy	Time at maximum range: 100 s and at minimum range: 1800 s	54
						Voltage	30 V to 300 V								
						Current	0.01 A to 120 A								
						Power factor	0.25 I/C to 1 I/C								
AC power and energy: three phase, reactive energy	Energy meters	Comparison	30	10800000	vars	Frequency	40 Hz to 70 Hz	(100 to 200)/sin ϕ	$\mu\text{varh}/\text{varh}$	2	95%	Yes	Three Phase Reactive Energy	Time at maximum range: 100 s and at minimum range: 1800 s	55
						Voltage	30 V to 300 V								
						Current	0.01 A to 120 A								
						Power factor	0.25 I/C to 1 I/C								

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AC power and energy: three phase, apparent energy	Energy meters	Comparison	90	10800000	VAs	Frequency	40 Hz to 70 Hz	100 to 200	μVAh/V Ah	2	95%	Yes	Three Phase Apparent Energy	Time at maximum range: 100 s and at minimum range: 1800 s	56
						Voltage	30 V to 300 V								
						Current	0.01 A to 120 A								
High DC voltage: high voltage sources	DC kilovolt source	Reference divider, digital voltmeter	1	100	kV			205	μV/V	2	95%	Yes			57
High DC voltage: high voltage meters	DC kilovolt meter	Reference divider, digital voltmeter	1	100	kV			205	μV/V	2	95%	Yes			58
High DC voltage: ratios	High voltage resistive divider	Comparison	100000:1 0	100000:10	V/V	Voltage	1 kV to 100 kV	200	μV/V	2	95%	Yes			59
AC high voltage: sources	AC high voltage source	Direct measureme nt	1	44	kV	Frequency	50 Hz	200 to 500	μV/V	2	95%	Yes			60
AC high voltage: meters	kV meter	Comparison	1	44	kV	Frequency	50 Hz	2 to 5	mV/V	2	95%	Yes			61
AC high voltage: ratio error and phase displacement	Voltage transformer, V.T. bridge	Comparison	110:110	44000:110	V/V	Frequency	50 Hz	200 to 500	μV/V	2	95%	Yes			62

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AC high voltage: ratio error and phase displacement	Voltage transformer, V.T. bridge	Comparison	110:110	44000:110	V/V	Frequency	50 Hz	60 to 120	μrad	2	95%	Yes			63
High AC current: sources	AC high current source	Direct measureme nt	1	5000	A	Frequency	50 Hz	2 to 5	mA/A	2	95%	Yes			64
High AC current: meters	AC high current meter	Comparison	1	5000	A	Frequency	50 Hz	2 to 5	mA/A	2	95%	Yes			65
High AC current: ratio error and phase displacement	Current transformer, CT bridge	Comparison	1/5	5000/5	A/A	Frequency	50 Hz	200 to 500	μA/A	2	95%	Yes			66
High AC current: ratio error and phase displacement	Current transformer, CT bridge	Comparison	1/5	5000/5	A/A	Frequency	50 Hz	60 to 120	μrad	2	95%	Yes			67
Magnetic field below 50 kHz: DC magnetic flux density and applied magnetic field strength	Magnetometer	NMR gaussmeter comparison	0.05	1.5	T			1 to 2	mT/T	2	95%	Yes			68
RF power: absolute power on coaxials	Generator, power meter	Direct measureme nt or comparison	0.01	100	mW	Frequency	1 MHz to 1 GHz	3 to 10	mW/W	2	95%	Yes	RF power		69
						Connector	N, APC-7								

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RF power: absolute power on coaxials	Generator, power meter	Direct measureme nt or comparison	0.01	10	mW	Frequency	1 GHz to 18 GHz	4 to 15	mW/W	2	95%	Yes	RF power		70
						Connector	N, APC-7								
RF power: calibration factor and effective efficiency of coaxials	Thermistor/ barretter mounts and power sensors	Direct comparison		100	%	Frequency	10 MHz to 18 GHz	0.2 to 1.0	%	2	95%	Yes			71
						Connectors	N, APC-7								
Scalar RF reflection coefficient and attenuation: reflection coefficient on coaxials	Coaxial matched terminations and standard mismatches	Coupled sliding load technique	1.02	5		Frequency	2 GHz to 18 GHz	0.02 in VSWR		2	95%	No			72
Scalar RF reflection coefficient and attenuation: reflection coefficient on waveguides	Waveguide matched terminations/ standard mismatches	Tuned reflectomet er technique	0.01	0.2		Frequency	5.8 GHz to 18 GHz (spot frequency)	0.002 to 0.003 in Reflection Coefficient		2	95%	No			73
Scalar RF reflection coefficient and attenuation: attenuation on coaxials	Waveguide below cut off (WBCO) attenuator	Substitution technique	0.05	60	dB	Frequency	30 MHz	0.007	dB/10 dB	2	95%	Yes			74

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Scalar RF reflection coefficient and attenuation: attenuation on coaxials	Fixed/ variable attenuators	Intermediate frequency substitution technique	0.1	60	dB	Frequency	1 GHz to 18 GHz	0.02	dB/10 dB	2	95%	Yes			75
Scalar RF reflection coefficient and attenuation: attenuation on waveguides	Fixed/ variable attenuators	Intermediate frequency substitution technique	0.1	60	dB	Frequency	5.8 GHz to 18 GHz	0.02	dB/10 dB	2	95%	Yes			76
RF voltage: RF/DC difference	RF micropotentiometers	Comparison	1	500	mV	Frequency	1 MHz to 100 MHz	0.1 to 10	mV/V	2	95%	Yes	RF-DC difference		77
RF voltage: RF/DC difference	RF micropotentiometers	Comparison	1	500	mV	Frequency	100 MHz to 1 GHz	2 to 20	mV/V	2	95%	Yes			78
RF voltage: RF/DC difference	Thermal converter	Comparison	0.25	50	V	Frequency	1 MHz to 50 MHz	0.1 to 1.5	mV/V	2	95%	Yes	RF-DC difference		79
RF voltage: RF/DC difference	Thermal converter	Comparison	1	7	V	Frequency	50 MHz to 1000 MHz	1.5 to 12	mV/V	2	95%	Yes	RF-DC difference		80
						Impedance	50 Ω								
RF voltage: sources	RF generators	Comparison	0.001	1	V	Frequency	1 MHz to 100 MHz	1 to 10	mV/V	2	95%	Yes	RF voltage (source)		81
						Impedance	50 Ω								
RF voltage: sources	RF generators	Comparison	0.001	1	V	Frequency	100 MHz to 1 GHz	5 to 30	mV/V	2	95%	Yes	RF voltage (source)		82

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						Impedance	50 Ω								
RF voltage: meters	RF millivoltmeter	Comparison	0.001	10	V	Frequency	1 MHz to 100 MHz	2 to 10	mV/V	2	95%	Yes	RF voltage (measurement)		83
RF voltage: meters	RF millivoltmeter	Comparison	0.001	7	V	Frequency	100 MHz to 1 GHz	8 to 30	mV/V	2	95%	Yes	RF voltage (measurement)		84
Lumped impedance/admit tance (using RF techniques): resistance	Resistors	RF impedance bridges / LCR meter	1	1E+06	Ω	Frequency	10 kHz to 60 MHz	1 to 30	m Ω / Ω	2	95%	Yes	RF Resistance		85
Lumped impedance/admit tance (using RF techniques): inductance	Inductors	RF impedance analyzer / LCR meter	0.05	1E+05	μ H	Frequency	10 kHz to 200 MHz	1 to 30	mH/H	2	95%	Yes	RF Inductance		86
Lumped impedance/admit tance (using RF techniques): capacitance	Capacitors	RF impedance analyser/LC R meter	1	1000	pF	Frequency	10 kHz to 100 MHz	0.2 to 30	mF/F	2	95%	Yes	RF Capacitance		87
Soft magnetic sheet materials: specific total power loss	Epstein samples	Epstein frame, according to IEC 60404-2	0.1	10	W/kg	Frequency	50 Hz to 400 Hz	2 to 20	m(W/kg) (W/kg)	2	95%	Yes			88

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Calibration or Measurement Service			Measurand Level or Range			Measurement Conditions/ Independent Variable		Expanded Uncertainty							
Quantity	Instrument or Artifact	Instrument Type or Method	Minimum Value	Maximum Value	Units	Parameter	Specifications	Value	Units	Coverage Factor	Level of Confidence	Is the expanded uncertainty a relative one?	Matrix uncertainty	Comments	NMI Service Identifier
						Peak value of magnetic polarization	1 T to 1.7 T								
Soft magnetic sheet materials: peak value of AC magnetic polarisation	Epstein samples	Epstein frame, according to IEC 60404-2	1	1.7	T	Frequency	50 Hz to 400 Hz	2 to 20	mT/T	2	95%	Yes			89
						Peak value of magnetic field strength	5 A/m to 10000 A/m								
Soft magnetic sheet materials: peak value of magnetic field strength	Epstein samples	Epstein frame, according to IEC 60404-2	5	10000	A/m	Frequency	50 Hz to 400 Hz	2 to 20	m(A/m)/ (A/m)	2	95%	Yes			90
						Peak value of magnetic polarization	1 T to 1.7 T								

Electricity and Magnetism, India, NPLI (National Physical Laboratory of India)

Calibration or Measurement Service			Measurand Level or Range			Measurement Conditions/ Independent Variable		Expanded Uncertainty							
Quantity	Instrument or Artifact	Instrument Type or Method	Minimum Value	Maximum Value	Units	Parameter	Specifications	Value	Units	Coverage Factor	Level of Confidence	Is the expanded uncertainty a relative one?	Matrix uncertainty	Comments	NMI Service Identifier
Soft magnetic sheet materials: specific apparent power	Epstein samples	Epstein frame, according to IEC 60404-2	0.5	250	VA/kg	Frequency	50 Hz to 400 Hz	10 to 50	m(VA/kg)/(VA/kg)	2	95%	Yes			91
						Peak value of magnetic polarization	1 T to 1.7 T								

Electricity and Magnetism, India, NPLI (National Physical Laboratory of India)

Uncertainty matrix: LF Capacitance Bridge

Capacitance: meters. Internal identifier: 30

	1 kHz
1E-03 pF to 10 pF	10 to 50
10 pF to 1000 pF	50
1E-03 μ F to 1 μ F	50 to 100

The expanded uncertainties given in this table are expressed in μ F/F.

Electricity and Magnetism, India, NPLI (National Physical Laboratory of India)

Uncertainty matrix: LF Inductance

Inductance: self inductance and equivalent series resistance, intermediate values. Internal identifier: 33

	Instrument	1 kHz
1 mH	Temperature controlled inductor	50
10 mH	Temperature controlled inductor	30
100 mH	Temperature controlled inductor	30
1mH to 100 mH	Inductor	100

The expanded uncertainties given in this table are expressed in $\mu\text{H}/\text{H}$.

Electricity and Magnetism, India, NPLI (National Physical Laboratory of India)

Uncertainty matrix: AC-DC voltage difference

AC/DC voltage transfer: AC/DC transfer difference. Internal identifier: 36, 37 and 38

	10 Hz, 20 Hz	40 Hz to 20 kHz	30 kHz to 70 kHz	100 kHz	30 kHz to 100 kHz	200 kHz to 300 kHz	500 kHz	700 kHz to 1 MHz
1 mV	200	190	-	-	200	300	500	1000
3 mV	190	170	-	-	200	250	400	800
10 mV	70	50	-	-	100	200	300	500
30 mV	70	60	-	-	80	100	200	300
100 mV	60	50	-	-	60	80	90	100
300 mV	30	20	-	-	30	50	55	60
500 mV	20	10	-	-	30	50	55	60
1 V	15	10	-	-	15	20	25	30
2 V	15	10	-	-	15	20	25	30
3 V	15	10	-	-	15	20	25	30
5 V	15	10	-	-	15	20	30	35
10 V	15	10	-	-	17	25	35	50
20 V	15	12	-	-	20	28	35	50
30 V	15	12	-	-	20	30	40	50
50 V	20	15	-	-	20	-	-	-
100 V	20	15	-	-	20	-	-	-
200 V	30	20	30	40	-	-	-	-
300 V	40	30	40	50	-	-	-	-
500 V	50	40	50	70	-	-	-	-
1000 V	70	60	70	100	-	-	-	-

The expanded uncertainties given in this table are expressed in $\mu\text{V/V}$.

Electricity and Magnetism, India, NPLI (National Physical Laboratory of India)

Uncertainty matrix: AC voltage (source)

AC voltage up to 1000 V: sources. Internal identifier: 39

	10 Hz, 20 Hz	40 Hz to 20 kHz	30 kHz to 70 kHz	100 kHz	30 kHz to 100 kHz	200 kHz to 300 kHz	500 kHz	700 kHz to 1 MHz
3 mV	250	200	-	-	200	300	500	1000
10 mV	120	100	-	-	150	250	350	550
30 mV	100	80	-	-	100	150	220	320
100 mV	80	60	-	-	80	100	170	250
300 mV	50	30	-	-	50	60	70	100
500 mV	30	20	-	-	30	55	60	70
1 V	25	20	-	-	25	30	35	40
2 V	25	20	-	-	25	30	35	40
3 V	25	20	-	-	25	30	35	40
5 V	25	20	-	-	25	30	40	45
10 V	30	25	-	-	30	35	50	60
20 V	30	20	-	-	30	40	50	60
30 V	30	20	-	-	30	40	55	70
50 V	30	25	-	-	35	-	-	-
100 V	35	20	-	-	40	-	-	-
200 V	40	30	40	50	-	-	-	-
300 V	50	40	50	60	-	-	-	-
500 V	60	50	80	100	-	-	-	-
1000 V	80	70	100	120	-	-	-	-

The expanded uncertainties given in this table are expressed in $\mu\text{V/V}$.

Electricity and Magnetism, India, NPLI (National Physical Laboratory of India)

Uncertainty matrix: AC voltage (measurement)

AC voltage up to 1000 V: meters. Internal identifier: 40

	10 Hz, 20 Hz	40 Hz to 20 kHz	30 kHz to 70 kHz	100 kHz	30 kHz to 100 kHz	200 kHz to 300 kHz	500 kHz	1 MHz
3 mV to 10 mV	250	200	-	-	200	200	500	1000
20 mV to 50 mV	120	100	-	-	150	200	250	300
70 mV to 100 mV	60	50	-	-	60	70	80	100
200 mV to 500 mV	35	30	-	-	30	35	40	50
1 V to 2 V	15	10	-	-	15	20	25	30
3 V to 5 V	15	12	-	-	15	25	35	40
10 V to 20 V	20	15	-	-	20	30	45	60
30 V to 70 V	25	20	30	40	-	-	-	-
100 V to 300 V	30	25	40	60	-	-	-	-
500 V	55	45	55	75	-	-	-	-
1000 V	75	65	75	110	-	-	-	-

The expanded uncertainties given in this table are expressed in $\mu\text{V/V}$.

Electricity and Magnetism, India, NPLI (National Physical Laboratory of India)

Uncertainty matrix: LF IVD

AC voltage ratio, attenuation and gain: real component. Internal identifier: 41

	55 Hz to 400 Hz	400 Hz to 1000 Hz	1 kHz to 10 kHz
10 V to 30 V	1E-06	-	-
30 V to 100 V	-	1E-06 to 5E-08	-
100 V	-	-	5E-08 to 1E-06

The expanded uncertainties given in this table are dimensionless.

Electricity and Magnetism, India, NPLI (National Physical Laboratory of India)

Uncertainty matrix: AC-DC current difference

AC/DC current transfer: AC/DC transfer difference. Internal identifier: 42

	40 Hz to 1 kHz	40 Hz to 5 kHz	2 kHz to 5 kHz	10 kHz
5 mA to 10 mA	-	20	-	30
30 mA	-	30	-	40
50 mA	-	30	-	45
100 mA	-	50	-	60
300 mA	-	50	-	60
500 mA	-	60	-	70
1 A	-	60	-	70
2 A	-	65	-	75
5 A	-	70	-	80
10 A	-	80	-	90
20 A	90	-	100	-

The expanded uncertainties given in this table are expressed in $\mu\text{A/A}$.

Electricity and Magnetism, India, NPLI (National Physical Laboratory of India)

Uncertainty matrix: AC current (source)

AC current up to 100 A: sources. Internal identifier: 43

	40 Hz to 1 kHz	40 Hz to 5 kHz	2 kHz to 5 kHz	10 kHz
1 A	-	100	-	150
2 A	-	100	-	150
3 A	-	100	-	150
5 A	-	100	-	150
10 A	-	100	-	150
20 A	100	-	200	-

The expanded uncertainties given in this table are expressed in $\mu\text{A/A}$.

Electricity and Magnetism, India, NPLI (National Physical Laboratory of India)

Uncertainty matrix: AC current (measurement)

AC current up to 100 A: meters. Internal identifier: 44

	40 Hz to 10 kHz
0.001 A	100
0.01 A	100
0.1 A	100
1 A	100

The expanded uncertainties given in this table are expressed in $\mu\text{A}/\text{A}$.

Electricity and Magnetism, India, NPLI (National Physical Laboratory of India)

Uncertainty matrix: Single Phase Active Power

AC power and energy: single phase power at frequency ≤ 400 Hz, active power. Internal identifier: 45

	Frequency range	Voltage	Current	Power factor	Expanded uncertainty
0.1 W to 8640 W	40 Hz to 70Hz	10 V to 288 V	0.01 A to 30 A	0.01 I/C to 1 I/C	$100/\cos\phi$
> 360 W to 69120 W	40 Hz to 70 Hz	120 V to 576 V	> 30 A to 120 A	0.1 I/C to 1 I/C	$(100 \text{ to } 200)/\cos\phi$
0.1 W to 8640 W	70 Hz to 400 Hz	10 V to 288 V	0.01 A to 30 A	0.1 I/C to 1 I/C	$200/\cos\phi$
> 360 W to 69120 W	70 Hz to 400 Hz	120 V to 576 V	> 30 A to 120 A	0.1 I/C to 1 I/C	$(200 \text{ to } 300)/\cos\phi$

The expanded uncertainties given in this table are expressed in $\mu\text{W/W}$.

Electricity and Magnetism, India, NPLI (National Physical Laboratory of India)

Uncertainty matrix: Single Phase Reactive Power

AC power and energy: single phase power at frequency ≤ 400 Hz, reactive power. Internal identifier: 46

	Frequency range	Voltage	Current	Power factor	Expanded uncertainty
0.1 vars to 8640 vars	40 Hz to 70 Hz	10 V to 288 V	0.01 A to 30 A	0.01 I/C to 1 I/C	$100/\sin\phi$
> 360 vars to 69120 vars	40 Hz to 70 Hz	120 V to 576 V	> 30 A to 120 A	0.1 I/C to 1 I/C	$(100 \text{ to } 200)/\sin\phi$

The expanded uncertainties given in this table are expressed in $\mu\text{var}/\text{var}$.

Electricity and Magnetism, India, NPLI (National Physical Laboratory of India)

Uncertainty matrix: Single Phase Apparent Power

AC power and energy: single phase power at frequency ≤ 400 Hz, apparent power. Internal identifier: 47

	Frequency range	Voltage	Current	Expanded uncertainty
0.3 VA to 25920 VA	40 Hz to 70 Hz	10 V to 288 V	0.01 A to 30 A	100
> 10800 VA to 207360 VA	40 Hz to 70 Hz	120 V to 576 V	> 30 A to 120 A	100 to 200

The expanded uncertainties given in this table are expressed in $\mu\text{VA}/\text{VA}$.

Electricity and Magnetism, India, NPLI (National Physical Laboratory of India)

Uncertainty matrix: Single Phase Active Energy

AC power and energy: single phase power at frequency ≤ 400 Hz, active energy. Internal identifier: 48

	Frequency range	Voltage	Current	Power factor	Expanded uncertainty
10 Ws to 864000 Ws	40 Hz to 70 Hz	30 V to 288 V	0.01 A to 30 A	0.25 I/C to 1 I/C	100/cos ϕ
> 900 Ws to 3600000 Ws	40 Hz to 70 Hz	120 V to 300 V	> 30 A to 120 A	0.25 I/C to 1 I/C	(100 to 200)/cos ϕ
40 Ws to 864000 Ws	70 Hz to 400 Hz	30 V to 288 V	0.05 A to 30 A	0.25 I/C to 1 I/C	200/cos ϕ
> 900 Ws to 3600000 Ws	70 Hz to 400 Hz	120 V to 300 V	> 30 A to 120 A	0.25 I/C to 1 I/C	(200 to 300)/cos ϕ

The expanded uncertainties given in this table are expressed in $\mu\text{Wh/Wh}$.

Electricity and Magnetism, India, NPLI (National Physical Laboratory of India)

Uncertainty matrix: Single Phase Reactive Energy

AC power and energy: single phase power at frequency ≤ 400 Hz, reactive energy. Internal identifier: 49

	Frequency range	Voltage	Current	Power factor	Expanded uncertainty
10 vars to 864000 vars	40 Hz to 70 Hz	10 V to 288 V	0.01 A to 30 A	0.01 I/C to 1 I/C	$100/\sin\phi$
> 900 vars to 3600000 vars	40 Hz to 70 Hz	120 V to 576 V	> 30 A to 120 A	0.1 I/C to 1 I/C	$(100 \text{ to } 200)/\sin\phi$

The expanded uncertainties given in this table are expressed in $\mu\text{varh}/\text{varh}$.

Electricity and Magnetism, India, NPLI (National Physical Laboratory of India)

Uncertainty matrix: Single Phase Apparent Energy

AC power and energy: single phase power at frequency ≤ 400 Hz, apparent energy. Internal identifier: 50

	Frequency range	Voltage	Current	Expanded uncertainty
30 VAs to 864000 VAs	40 Hz to 70 Hz	30 V to 288 V	0.01 A to 30 A	100
> 3600 VAs to 3600000 VAs	40 Hz to 70 Hz	120 V to 300 V	> 30 A to 120 A	100 to 200

The expanded uncertainties given in this table are expressed in $\mu\text{VAh}/\text{VAh}$.

Electricity and Magnetism, India, NPLI (National Physical Laboratory of India)

Uncertainty matrix: Three Phase Active Power

AC power and energy: three phase power, active power. Internal identifier: 51

	Frequency range	Voltage	Current	Power factor	Expanded uncertainty
0.3 W to 25920 W	40 Hz to 70 Hz	10 V to 288 V	0.01 A to 30 A	0.01 I/C to 1 I/C	$100/\cos\phi$
> 1080 W to 207360 W	40 Hz to 70 Hz	120 V to 576 V	> 30 A to 120 A	0.1 I/C to 1 I/C	$(100 \text{ to } 200)/\cos\phi$
0.3 W to 25920 W	70 Hz to 400 Hz	10 V to 288 V	0.01 A to 30 A	0.1 I/C to 1 I/C	$200/\cos\phi$
> 1080 W to 207360 W	70 Hz to 400 Hz	120 V to 576 V	> 30 A to 120 A	0.1 I/C to 1 I/C	$(200 \text{ to } 300)/\cos\phi$

The expanded uncertainties given in this table are expressed in $\mu\text{W}/\text{W}$.

Electricity and Magnetism, India, NPLI (National Physical Laboratory of India)

Uncertainty matrix: Three Phase Reactive Power

AC power and energy: single phase power, reactive power. Internal identifier: 52

	Frequency range	Voltage	Current	Power factor	Expanded uncertainty
0.3 var to 25920 var	40 Hz to 70 Hz	10 V to 288 V	0.01 A to 30 A	0.01 I/C to 1 I/C	100/sin ϕ
> 1080 var to 207360 var	40 Hz to 70 Hz	120 V to 576 V	> 30 A to 120 A	0.1 I/C to 1 I/C	(100 to 200)/sin ϕ

The expanded uncertainties given in this table are expressed in $\mu\text{var}/\text{var}$.

Electricity and Magnetism, India, NPLI (National Physical Laboratory of India)

Uncertainty matrix: Three Phase Apparent Power

AC power and energy: single phase power, apparent power. Internal identifier: 53

	Frequency range	Voltage	Current	Expanded uncertainty
0.3 VA to 25920 VA	40 Hz to 70 Hz	10 V to 288 V	0.01 A to 30 A	100
> 10800 VA to 207360 VA	40 Hz to 70 Hz	120 V to 576 V	> 30 A to 120 A	100 to 200

The expanded uncertainties given in this table are expressed in $\mu\text{VA}/\text{VA}$.

Electricity and Magnetism, India, NPLI (National Physical Laboratory of India)

Uncertainty matrix: Three Phase Active Energy

AC power and energy: three phase, active energy. Internal identifier: 54

	Frequency range	Voltage	Current	Power factor	Expanded uncertainty
30 Ws to 2592000 Ws	40 Hz to 70 Hz	30 V to 288 V	0.01 A to 30 A	0.25 I/C to 1 I/C	100/cos ϕ
> 2700 Ws to 10800000 Ws	40 Hz to 70 Hz	120 V to 300 V	> 30 A to 120 A	0.25 I/C to 1 I/C	(100 to 200)/cos ϕ
120 Ws to 2592000 Ws	70 Hz to 400 Hz	30 V to 288 V	0.05 A to 30 A	0.25 I/C to 1 I/C	200/cos ϕ
> 2700 Ws to 10800000 Ws	70 Hz to 400 Hz	120 V to 300 V	> 30 A to 120 A	0.25 I/C to 1 I/C	(200 to 300)/cos ϕ

The expanded uncertainties given in this table are expressed in $\mu\text{Wh/Wh}$.

Electricity and Magnetism, India, NPLI (National Physical Laboratory of India)

Uncertainty matrix: Three Phase Reactive Energy

AC power and energy: three phase, reactive energy. Internal identifier: 55

	Frequency range	Voltage	Current	Power factor	Expanded uncertainty
30 vars to 2592000 vars	40 Hz to 70 Hz	10 V to 288 V	0.01 A to 30 A	0.01 I/C to 1 I/C	100/sin ϕ
> 2700 vars to 10800000 vars	40 Hz to 70 Hz	120 V to 576 V	> 30 A to 120 A	0.1 I/C to 1 I/C	(100 to 200)/sin ϕ

The expanded uncertainties given in this table are expressed in $\mu\text{varh}/\text{varh}$.

Electricity and Magnetism, India, NPLI (National Physical Laboratory of India)

Uncertainty matrix: Three Phase Apparent Energy

AC power and energy: three phase, apparent energy. Internal identifier: 56

	Frequency range	Voltage	Current	Expanded uncertainty
90 VAs to 2592000 VAs	40 Hz to 70 Hz	30 V to 288 V	0.01 A to 30 A	100
> 10800 VAs to 10800000 VAs	40 Hz to 70 Hz	120 V to 300 V	> 30 A to 120 A	100 to 200

The expanded uncertainties given in this table are expressed in $\mu\text{VAh}/\text{VAh}$.

Electricity and Magnetism, India, NPLI (National Physical Laboratory of India)

Uncertainty matrix: RF power

RF power: absolute power on coaxials. Internal identifier: 69 and 70

	1 MHz to 1 GHz	1 GHz to 18 GHz
0.01 mW to 0.1 mW	5 to 10	15
0.1 mW to 1 mW	3 to 5	4 to 15
1 mW to 10 mW	3	4 to 10
10 mW to 100 mW	3	-

The expanded uncertainties given in this table are expressed in mW/W.

Electricity and Magnetism, India, NPLI (National Physical Laboratory of India)

Uncertainty matrix: RF-DC difference

RF voltage: RF-DC difference. Internal identifier: 77, 79 and 80.

	1 MHz to 10 MHz	10 MHz to 50 MHz	10 MHz to 100 MHz	50 MHz to 500 MHz	100 MHz to 1 GHz	500 MHz to 1 GHz
1 mV to 10 mV	1 to 5	-	2 to 10	-	-	-
10 mV to 100 mV	0.5 to 2	-	1 to 5	-	-	-
100 mV to 500 mV	0.1 to 1.0	-	1 to 5	-	-	-
0.25 V to 50 V	0.1 to 0.3	0.3 to 1.5	-	-	-	-
1 V to 7 V	-	-	-	1.5 to 9	-	9 to 12

The expanded uncertainties given in this table are expressed in mV/V.

Electricity and Magnetism, India, NPLI (National Physical Laboratory of India)

Uncertainty matrix: RF voltage (source)

RF voltage: sources. Internal identifier: 81 and 82

	1 MHz to 100 MHz	100 MHz to 1 GHz
0.001 V to 0.01 V	5 to 10	30
0.01 V to 0.25 V	1 to 7	7 to 30
0.25 V to 1 V	1 to 5	5 to 20

The expanded uncertainties given in this table are expressed in mV/V.

Electricity and Magnetism, India, NPLI (National Physical Laboratory of India)

Uncertainty matrix: RF voltage (measurement)

RF voltage: meters. Internal identifier: 83 and 84

	1 MHz to 100 MHz	100 MHz to 1 GHz
0.001 V to 0.01 V	5 to 10	30
0.01 V to 0.25 V	2 to 10	10 to 30
0.25 V to 10 V	2 to 8	-
0.25 V to 7 V	-	8 to 25

The expanded uncertainties given in this table are expressed in mV/V.

Electricity and Magnetism, India, NPLI (National Physical Laboratory of India)

Uncertainty matrix: RF Resistance

Lumped impedance/admittance: resistance. Internal identifier: 85.

	10 kHz to 100 kHz	10 kHz to 1 MHz	3 MHz to 10 MHz	1 MHz to 30 MHz	30 MHz to 60 MHz
35 Ω to 100 Ω	-	-	-	1 to 2	2 to 10
1 Ω to 100 Ω	-	5 to 2	10 to 3	-	-
200 Ω to 1000 Ω	-	1	3	-	-
2 k Ω to 10 k Ω	-	2 to 3	10 to 20	-	-
20 k Ω to 100 k Ω	-	5 to 20	-	-	-
200 k Ω to 1000 k Ω	20 to 30	-	-	-	-

The expanded uncertainties given in this table are expressed in m Ω/Ω .

Electricity and Magnetism, India, NPLI (National Physical Laboratory of India)

Uncertainty matrix: RF Inductance

Lumped impedance/admittance: inductance. Internal identifier: 86.

	10 kHz to 1 MHz	50 kHz to 2 MHz	1 MHz to 50 MHz	3 MHz to 10 MHz	25 MHz to 200 MHz
0.05 μH to 0.5 μH	-	-	-	-	5 to 15
1 μH to 50 μH	-	-	5 to 10	-	-
0.1 mH to 25 mH	-	15	-	-	-
10 μH to 1000 μH	1 to 5	-	-	10 to 30	-
10 mH to 100 mH	1 to 5	-	-	-	-

The expanded uncertainties given in this table are expressed in mH/H.

Electricity and Magnetism, India, NPLI (National Physical Laboratory of India)

Uncertainty matrix: RF Capacitance

Lumped impedance/admittance: capacitance. Internal identifier: 87.

	10 kHz to 1 MHz	1 MHz to 10 MHz	3 MHz to 10 MHz	10 MHz to 100 MHz
1 pF to 20 pF	0.2 to 0.5	1	-	1 to 2
20 pF to 1000 pF	0.5 to 1	-	-	-
1 pF to 100 pF	-	-	5 to 20	-
200 pF to 1000 pF	-	-	10 to 30	-

The expanded uncertainties given in this table are expressed in mF/F.